Final Report

ASR Benchmarking Workshop

August 2006

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Federal Highway Administration

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Mr. Mark Swanlund and Ms. Gina Ahlstrom of Federal Highway Administration served as the Contracting Officer's Technical Representatives for this project. This ASR Benchmark Workshop was organized and facilitated by Burns Cooley Dennis, Inc. in conjunction with the Federal Highway Administration.

16. Abstract

A two and one-half day ASR Benchmarking Workshop was held between June 6 and 8, 2006 as part of the Federal Highway Administration's (FHWA's) effort to develop elements for an alkali-silica reactivity (ASR) Program. The need for this facilitated workshop was born out of the recently passed legislation entitled Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

The objective of this workshop was to gather expert and stakeholder input regarding a comprehensive program of further development and deployment activities addressing techniques available presently and in the very near future to prevent and mitigate ASR. A total of 74 participants attended the workshop. Participants were from academia, industry, State Departments of Transportation, government agencies, and the host agency FHWA. Organization of the workshop was designed to bring forward presently available information regarding the state of technology, challenges faced with preventing and mitigating ASR and the methods that can be deployed in the field.

Four topics were addressed during the discussion group sessions at the workshop: 1) ASR test methods and identification techniques; 2) ASR prevention in new construction and current specifications; 3) ASR mitigation in existing concrete; and 4) how do we approach the inventory of structures and pavements. This report provides a summary of discussions from each of the breakout groups as well as the recommended elements for the ASR program as discussed by the assembled group.

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BACKGROUND

A two and one-half day facilitated workshop was held between June 6 and 8, 2006 at the Wyndham-O'Hare hotel in Chicago, Illinois, as part of the Federal Highway Administration's (FHWA's) effort to develop elements for a future alkali-silica reactivity (ASR) program. The need for this facilitated workshop was born out of the requirements in the recently passed legislation entitled Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy of Users (SAFETEA-LU). The following was provided within SAFTEA-LU:

> **SEC. 5203. (e) DEMONSTRATION PROJECTS AND STUDIES**
>
> **(3) ALKALI SILICA REACTIVITY**. Of the funds made available by section 5101 (a) (1) of this Act, $2,450,000 shall be made available by the Secretary for each of fiscal years 2006 through 2009 for further development and deployment techniques to prevent and mitigate alkali silica reactivity.
>
> *Conference Report*
> The Conference adopts the House provision with some modifications. Alternative materials, asphalt, and alkali silica reactivity (ASR) authorized under Senate section 2001 are added to this section. Project and programs related to ASR should further development and deployment of techniques to prevent and mitigate alkali-silica reactivity, including lithium based techniques, and assist states in inventorying existing structures.

Based upon this legislation, the FHWA must develop a program that further develops and deploys techniques to prevent and mitigate ASR in portland cement concrete (PCC) pavements and structures. In order to develop this program, information was needed to determine the current state of knowledge related to ASR and to receive stakeholder input prior to the formation of the ASR development and deployment program authorized by the legislation. The first step in this information gathering stage was to organize and conduct the ASR Benchmarking Workshop.

WORKSHOP OBJECTIVES

The objective of this workshop was to gather expert and stakeholder input regarding a comprehensive program of development and deployment activities addressing techniques to prevent and mitigate ASR. Participants were asked to identify potential program elements for this ASR program that will be administered by the FHWA.

WORKSHOP ORGANIZATION

A total of 74 participants attended the workshop. The participants were grouped into one of seven categories: from academia, industry, State Departments of Transportation, the host agency FHWA, other government agencies, staff, and guest. All were invited to participate in discussion groups except for guests who observed the Workshop and

FHWA representatives whose primary function was to listen and gather information. Invited participants were specifically selected because of their knowledge and experience related to ASR. A listing of all participants of the workshop is provided in Attachment A.

Organization of the workshop was designed to maximize the amount of information regarding the present state of the technology, challenges faced with preventing and mitigating ASR, and the methods that can be deployed in the field. Attachment B presents the Agenda for the workshop. Initially, prominent individuals with knowledge of ASR issues made presentations establishing the current state-of-practice related to ASR. Presentations were made on test methods currently used to evaluate the potential for deleterious ASR, results of the ASR Strategic Highway Research Program (SHRP) and AASHTO Lead State Programs for ASR, current initiatives using lithium to mitigate ASR, experiences of the Federal Aviation Administration and Department of Defense with ASR, and ASR's impact on long life infrastructure. Attachment C provides a summary of these various presentations.

Following the presentations, the workshop participants were divided into four discussion groups, each with a Discussion Group Leader and a Recorder. These groups discussed the current state-of-practice on ASR and where future development and deployment are required. The process entailed each group participating in a breakout session and discussing broad topics relating to ASR. After the allotted time for the breakout session, all participants reconvened and each group provided a summary of their discussions and recommended elements for the ASR program. Finally, the workshop facilitator along with all participants developed a summary of common themes and activities recommended for future development and deployment.

Four topics were discussed in the breakout sessions: 1) ASR test methods and identification techniques; 2) ASR prevention in new construction and current specifications; 3) ASR mitigation in existing concrete; and 4) how do we approach the required inventory of structures and pavements. Prior to the breakout sessions, the discussion group leaders and workshop participants were provided the following points to keep in mind during their discussions:

- Stay focused on the SAFETEA-LU legislative requirements and the associated conference report.
- The ASR Program needs to be accomplished within the time constraints of the legislation and within the available funding.
- Key questions that need to be asked:
    1. What have we learned so far in ASR research, field performance and implementation technology?
    2. Where we are today with ASR research and what technology can we take to implementation now or in the very near future?
    3. What do we need to know and where are the research gaps?
- Keep the big picture in mind. Keep the discussion on highly technical issues to a minimum.

- Provide recommendations for elements of the ASR Program and their relative importance.

WORKSHOP SUMMARY

This section provides a summary of the breakout group discussions and the recommended elements identified by the participants of the ASR Benchmarking Workshop. The summary of each of the four discussion topics is provided in addition to a summary of the recommended elements the participants identified for the ASR program.

Discussion Topic Summaries

The following summarizes the discussions of the four breakout sessions held during the ASR Benchmarking Workshop.

Topic #1 – ASR Test Methods and Identification Techniques

The first breakout session dealt with methods of testing and identifying ASR. During discussions on this topic, a number of test methods and identification procedures were recognized, which included:

- ASTM C289, Test Method for Potential Alkali – Silica Reactivity of Aggregates (Chemical Method)
- ASTM C 295, Guide for Petrographic Examination of Aggregates for Concrete
- ASTM C 856, Standard Practice for Petrographic Examination of Hardened Concrete
- ASTM C 1260, Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- ASTM C1293, Test Method for Determination of Length of Change of Concrete Due to Alkali-Silica Reactivity
- ASTM C1567, Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitous Materials and Aggregates (Accelerated Mortar-Bar Method)

There was much discussion on the shortcomings of each test method. These tests are not based upon the fundamental scientific properties of ASR development in concrete. Rather, they are inference tests, which provide information for making a “go/no go” decision. Most of these test methods only evaluate aggregates and do not evaluate the actual concrete mixture design selected for that particular structure. Testing the concrete mixtures in conditions similar to field exposure is essential. Therefore, these tests are not directly related to field performance. Another major issue mentioned with many of the current ASR tests is the duration of the tests required to obtain a reliable answer. During the time required for the test, material availability of cement and aggregate may change. When tests are performed that requires a shorter testing duration, specification criteria for material acceptance is generally over-conservative. The most important shortcoming of the various tests listed above is that most practitioners do not understand the test methods.

Also noted was that the test methods do not provide for convenient evaluation of specific proposed combinations of cementitious materials, aggregates and admixtures. Another shortcoming identified was that petrographers require more experience in identifying ASR.

The ideal components for testing the ASR potential of both aggregates and concrete mixtures were discussed. An ideal test for the ASR potential of aggregates would have the following components:

- inexpensive, fast, and easy to run
- accurate and reliable such that the user has confidence in the results
- relate to field performance
- test aggregate sizes and actual blends that are utilized in concrete mixtures
- applicable for Quality Assurance

The ideal components for testing the ASR potential of a concrete mixture were also discussed. An ideal test for the ASR potential of a concrete mixture would have the following components:

- inexpensive and fast
- related to field performance
- test uses the actual concrete mixture that will be used on the project

The future development of “smart” mixes, such as self healing concrete, using nanotechnology was also discussed. If the basic mechanisms of ASR were better understood, the ASR reaction might be better controlled or limited to avoid deleterious expansion in typical applications for highway structures and concrete pavements.

Participants agreed that field identification of ASR is difficult. The primary problem is that the early stages of deleterious ASR is difficult to visually identify. Petrographic examinations are expensive and most agencies have limited resources (money, personnel, and expertise). An ideal test to identify ASR would be conducted in the field. The test would be relatively easy, fast, and reliable. Ideally the results of the test would provide an estimate of remaining service life for the concrete element.

There were a number of knowledge gaps related to testing and identifying ASR in concrete. A common theme identified was the lack of qualified personnel and laboratories around the country. Also, there is a lack of understanding of the extent of the problem because ASR is not easily identified and is not included as part of most regular pavement or bridge inspection programs or procedures. Without understanding the extent of the problem, many agencies are not initiating methods or research to address ASR. Further investigation of the basic mechanisms causing ASR was mentioned as a gap in knowledge. Another gap mentioned by all of the discussion groups was the lack of a fundamental-based system for testing and identifying potential ASR problems.

Topic #2 – ASR Prevention in New Construction and Current Specifications

A number of methods for preventing ASR in new construction were discussed. The three primary methods are: screen aggregate sources for reactive aggregates, control or limit the alkalis in the mixture, and the use of supplementary cementitous materials (SCMs). SCMs include fly ash, ground granulated blast furnace slag (GGBFS), silica fume, or combinations of these SCMs. A fast and reliable test method for identifying ASR potential in concrete mixtures is needed.

Participants also discussed improving the decision making process for preventing ASR in new construction. At the forefront of this discussion was increasing the awareness of ASR through education and increasing information sharing between agencies. There was a discussion on revisiting the procedures of concrete mix design, in which durability, rather than strength, would be emphasized. This philosophy would address ASR in addition to all durability distresses. Also needed is a protocol for monitoring the effectiveness of mix design tests with respect to field performance.

New or promising technologies for preventing ASR in new construction included adding lithium to the concrete as an admixture. The use of lithium in combination with SCMs in new concrete mixtures was identified as a promising technology that needs to be evaluated both for technical and economic reasons. The addition of lithium in new concrete mixtures should be further evaluated for its ability to prevent ASR in new construction. There was discussion about the benefits of fly ash; however, the type of fly ash and its range of chemical composition utilized affects ASR potential. Another SCM mentioned by the participants was kaolin clay. Metakaolin is one product that can be added that has shown promise in preventing ASR. Other natural pozzolans may also help prevent ASR in new construction.

A number of knowledge gaps were identified for the prevention of ASR in new construction. The amount or dosage of lithium, SCMs, and natural pozzolans needs to be further evaluated. This is especially true considering the wide variability of materials. Field trials using the various additives, which have been proven to mitigate ASR in the laboratory need to be utilized in the field and monitored for extended periods of time for correlation. A database of results for field trials, including the mixture designs from the field trials, would provide valuable information and could be used to identify successful and unsuccessful preventative methods. Another gap identified was the lack of early detection for ASR. Development of an "early warning system," which indicates potential expansion of a structure would be useful for early mitigation of ASR. Once again, the lack of education was considered a gap in current practice. Updating existing guide specifications, inspection protocols, and evaluation protocols are needed. These documents need to be included in training for agency, contractor and consulting personnel.

There were some differences among the discussion groups when it came to specifications for preventing ASR in new construction. Some participants felt that prescriptive specifications should be utilized while others believed that performance based specifications should be used.

A number of barriers to the implementation of new and promising technologies for prevention of ASR in new construction were discussed. Barriers such as politics, initial costs, material supply available locally or regionally, lack of adequate test methods, and consistent application of specifications, and resistance to change were all discussed. A lack of education and awareness of ASR was also mentioned.

Topic #3 – ASR Mitigation in Existing Concrete

There are a number of methods to identify ASR in existing concrete. Petrography, staining techniques, and scanning electron microscopes were all discussed under this topic. Techniques to mitigate ASR were identified. Three methods of applying lithium to existing concrete were mentioned: topical application, vacuum impregnation, and electrochemical methods. Another mitigation technique was the application of silane, which seals the concrete and prevents or minimizes moisture ingress and subsequently reduces the potential for deleterious expansion. For pavements, various options were discussed which included: asphalt overlay, bonded PCC overlay with lithium, rubbilization, crack and seat, or recycling the concrete. Although these techniques were mentioned they should not be considered as mitigation methods as they are not necessarily stopping or slowing down the ASR mechanism. Also, these techniques may not work as there are issues with the amount of expansion that is remaining in the structure and the ability to eliminate moisture. For concrete structures, one mitigation option mentioned was restraining the element to prevent excessive expansion. Agency representatives indicated they would like an estimate of service life for the various mitigation techniques. This would allow agencies to perform a cost/benefit analysis and determine if and when replacement of the structure is necessary.

A number of knowledge gaps in the current state-of-practice of various mitigation methods were also discussed. The penetration depth of lithium remains in question. Field trials as part of FHWA's Lithium Technology Program are underway; however, additional development efforts may be warranted. The intent of the mitigation methods remains in question. Guidance needs to be provided on the service life of these methods and if they should be used as short-term or long-term solutions. Many felt the use of these mitigation methods are relatively new and more long-term performance histories are needed. More field trials would be beneficial to gain more information regarding the service life of these methods. Finally, a field test to evaluate the existence of ASR in existing concrete would be beneficial as elaborated under Discussion Topic Summary, Topic #1-ASR Test Methods and Identification Techniques.

Barriers to implementing new promising mitigation techniques include knowledge of the ASR mechanism, lack of qualified applicators, costs, and the lack of evidence regarding the success of the techniques. There is a lack in understanding the role that deicers and anti-icing materials play in the development of deleterious ASR. The highway and airfield pavement industries have indicated that deicers, particularly potassium and sodium acetate deicers, have in some instances accelerated, or caused, concrete expansion due to ASR.

Topic #4 – How Do We Approach The Inventory of Structures and Pavements?

One of the biggest problems the participants noted about inventorying structures and pavements for ASR is that very few people have experience in visually identifying ASR in the field. At least one agency represented at the workshop has addressed this issue by providing a handbook for identifying ASR to field personnel. In addition, some agencies do not evaluate structures or pavements specifically for ASR; therefore ASR is not included on maintenance or inspection data sheets.

One of the primary benefits of including ASR in an inspection management database is that results can be used to track the rate of development of ASR. This information would be important for decision makers regarding mitigation needs.

The identification of ASR in State structures and concrete pavements is included in the legislative intent for FHWA's ASR development and deployment program. The first step is for ASR indicators in a State's current structure and pavement inspection program. After the initial indication that ASR may be present in a structure, further examination, including petrography, should be used to verify the presence of ASR. If the presence of ASR is confirmed in a structure or pavement, the progression of ASR would be monitored. Participants indicated that ideally a test for the identification of ASR would be fast, reliable, and could be used in the field.

Participants discussed two primary methods that are utilized to monitor concrete highway structures: visual condition surveys and automated inspection systems. When using these automated inspection systems, the participants indicated that higher resolution photos would enhance the ability to identify distresses caused by ASR.

RECOMMENDED ELEMENTS FOR ASR PROGRAM

The need for this workshop arose from the recent passage of the SAFETEA-LU legislation. The objectives of the workshop were to identify potential program elements for an ASR Development and Deployment Program. After all groups discussed the four topics related to ASR the workshop facilitator reconvened the groups and identified common elements that were identified by the workshop participants. The recommended elements for the ASR program that were identified by all or a majority of the discussion group members are as follows:

Topic #1 – ASR Test Methods and Identification Techniques

- Establish a process and protocol to evaluate and correlate existing and emerging data to field performance
- Establish models to predict the occurrence of deleterious ASR
- Evaluate new test methods (e.g. non-destructive evaluations and nanotechnology)
- Develop more accurate, fast, and reliable tests that can be integrated into the protocol
- Provide technology transfer/delivery/training
- Utilize existing tests to develop protocols that relate to field conditions and performance – including mitigation strategies

Topic #2 – ASR Prevention in New Construction Existing Tools and Guide Specification for Durable Concrete

- Develop protocol or a framework using existing tools and guide specifications for durable concrete
- Further evaluate and monitor the effectiveness of existing tools
  - Field trials
- Provide training and education
- Develop a quick and reliable performance related test
  - Test for constituent (aggregate, cement, SCMs, etc.)
  - Test for concrete mixture
- Better trained petrographers
- Utilize Canadian Standards Association (CSA) protocol
  - Validate framework and parameters for the United States
- Address gaps

Topic #3 – ASR Mitigation in Existing Concrete

- Further refine mitigation techniques
- Further define optional timing and/or rate for mitigation techniques
  - At what point should mitigation be considered
- Develop a database of maintenance and repair strategies
  - Timing

  - Rate
  - Performance
- Develop protocol/framework/decision tree, using existing techniques and guide specifications for durable concrete
- Further evaluate/monitor effectiveness of existing techniques
  - Field trials
- Develop a quick field test to identify if and when ASR has occurred
  - How much
  - When it started
  - How much expansion is left

Topic #4 – How Do We Approach The Inventory of Structures and Pavements?

- Develop guidance for visually identifying potential ASR
  - Uniformity in visual examination
- Develop a "litmus" field test to identify the existence of expansive ASR
- Develop framework for inventory and prioritizing through the existing Pavement Management and Bridge Management Systems
  - Rating system (severity)
  - Continuous monitoring

CONCLUSION

This report summarizes the discussions and conclusions of the ASR Benchmarking Workshop held between June 6 and 8, 2006 in Chicago, Illinois. An account of the discussion group sessions and the recommended elements for the ASR program that were identified by all or a majority of the discussion group members is presented in this report. The FHWA and the ASR Development and Deployment Program Technical Working Group will utilize this report when furthering the development of the ASR Program.

ATTACHMENT A

ASR Benchmarking Workshop

Attendees

FULL NAME	ORGANIZATION	FULL NAME	ORGANIZATION
Gina Ahlstrom	FHWA/Off. of Pav't. Tech.	Rick Meininger	FHWA/Pavement R&D
Roger Apple	Pennsylvania DOT	Brian Merrill	Texas DOT
Ahmad Ardani	Colorado DOT	James Moore	New Hampshire DOT
Emmanuel Attiogbe	Degussa USA	Jon Mullarky	FHWA/Off. of Pav't. Tech.
Myron Banks	Georgia DOT	Mohammed Nabulsi	MA DOT
Jill R. Baumgardner	Burns Cooley Dennis, Inc.	Norm Nelson	Lyman-Richey Corp.
Sarah Berman	FHWA/Office of Acq. Mgmnt.	Charles Nurse	FHWA/Office of Acq. Mgmnt
Jimmy W. Brumfield	Burns Cooley Dennis, Inc.	Marvin Obermyer, P.E.	Buzzi Unicem USA
John Bukowski	FHWA/Off. of Pav't. Tech.	Hratch Pakchanian	FHWA Eastern Federal Lands
Francois Chapdelaine	Materials Service Life	Jim Pappas	Delaware DOT/Materials Div.
Allen Cooley	Burns Cooley Dennis, Inc.	James Pierce	US Bureau of Reclemation
Angel Correa	FHWA/Resource Center	Toy Poole	US Army Corps of Engineers
Gary Crawford	FHWA/Off. of Pav't. Tech.	James Powell	Vulcan Materials Co.
Greg Daderko	Lafarge	Prasad Rangaraju	Clemson University
Lizanne Davis	FMC Corp.	Jeffrey Rapol	Federal Aviation Administration
Doug Dirks	Illinois DOT	Kenneth Rear	Heidelberg Tech Cntr./Lehigh
Tim Durning	W. R. Grace Company	Cheryl Richter	FHWA/Office of R&D
Fred Faridazar	FHWA/Office of R&D	Randell Riley, P.E.	ACPA
Anthony Fiorato	CTL Group	Robert Rothwell	Wyoming DOT
Benoit Fournier	CANMET	Walter Rowe	Consulting Engineer
David Gress	University of New Hampshire	Jack Scott	FAA, NW Mountain Region
James Grove	Nat'l CP Tech Center/Iowa State	Surendra Shah	Northwestern University
Bob Harris	Nutter & Harris	Terry W. Sherman	US Army Corps of Engineers
Joey Hartmann	FHWA/Office of R&D	David Stokes	FMC Corp.
Gary Henderson	FHWA/Office of R&D	Leslie Struble	University of Illinois at Urbana
Clint Hoops	Idaho DOT	Paul Stutzman	NIST
Doug Hooton	University of Toronto	Roger Surdahl	FHWA/Federal Lands
David Huft	South Dakota DOT	Gregory Sweeney	FAA/Illinois Division
Francis Innis	Holcim/PCA	Shiraz Tayabji	CTL Group
Gary Jakovick	FHWA Office of Bridge Tech.	Paul G. Tourney, P.E.	Tourney Consulting Group, LLC
Moe Jamshidi	Nebraska Dept. of Roads	Thomas Van Dam	Michigan Tech University
Cecil L. Jones	North Carolina DOT	Suneel Vanikar	FHWA/Off. of Pav't. Tech.
Bill Korkowski	Buzzi Unicem USA	Paul Virmani	FHWA/Bridge R&D
Steven Kosmatka	Portland Cement Association	Gerald Voigt	ACPA
Stephen Lane	VA Research Council	Leif Wathne	ACPA
Colin Lobo	NRMCA	Nancy Whiting	Minnesota DOT
Orange Marshall, Jr.	US Army Corps of Engineers	David Whitmore	Vector Corrosion Technologies, Ltd.
		Dan Zollinger	Texas A&M University

ATTACHMENT B

ALKALI-SILICA REACTIVITY (ASR) BENCHMARKING WORKSHOP

June 6- 8, 2006
Chicago, Illinois

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DAY 1 – Tuesday, June 6, 2006

7:00-8:00 **Registration.** *(Foyer Outside Salons A, B, and C)*

8:00 **Call to Order.** *(Salon B)*
Mr. Jimmy Brumfield, Facilitator

8:00-8:15 **Welcome. SAFETEA-LU legislation and goals/outcome of Workshop.** *(Salon B)*
Mr. Gary Henderson - Director, Office of Infrastructure Research and Development, Federal Highway Administration

8:15-8:30 **ASR development and deployment procurement plan.** *(Salon B)*
Mr. Charles Nurse – Contracting Officer, Office of Acquisition Management, Federal Highway Administration
AND
Ms. Sarah Berman – Contracting Specialist, Office of Acquisition Management, Federal Highway Administration

8:30-9:00 **ASR in highway structures and pavements: What have we learned and what do we still need to know from research?** *(Salon B)*
Dr. Surendra Shah – Director, Center for Advanced Cement-Based Materials (ACBM)

9:00-9:30 **An industry perspective on implementation of ASR requirements in specifications for concrete bridges and pavements.** *(Salon B)*
Dr. Anthony Fiorato – Chairman of the Board, ASTM International

9:30-10:00 **Results of the ASR SHRP Implementation Program and the AASHTO LEAD States Program from a State perspective**. *(Salon B)*
Mr. Cecil Jones – State Materials Engineer, North Carolina Department of Transportation

10:00-10:15 **Break**

10:15-11:00 **What can be implemented from the current research program.** *(Salon B)*
Dr. Benoit Fournier – Manager of Advanced Concrete, CANMET

11:00-11:30 **Federal Aviation Administration (FAA) experience with ASR.** *(Salon B)*
Mr. Jack Scott – Civil Engineer, Safety and Standards Branch, Northwest Mountain Region, Federal Aviation Administration

11:30-12:00 **Department of Defense (DOD) experience with ASR.** *(Salon B)*
Mr. Terry Sherman – Director, Transportation Systems Center, US Army Corps of Engineers

12:00-1:30 **Lunch** *(On your own)*

1:30-1:45 **Objectives of Workshop and ground rules for discussion groups.** *(Salon B)*
Mr. Jimmy Brumfield - Facilitator

1:45-3:30 **ASR test methods and identification techniques.** *(Salons A and C)*
Breakout group discussions on Topic #1

3:30-3:45 **Break**

3:45-4:45 **Summary presentations from Group Leaders and group recommendations on Topic #1.** *(Salon B)*
Mr. Jimmy Brumfield - Facilitator

4:45-5:00 **Wrap-up of Day 1.** *(Salon B)*
Mr. Jimmy Brumfield – Facilitator

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DAY 2 – Wednesday, June 7, 2006

7:00-7:45 **FHWA, Office of Acquisitions Management is available for questions comments.** *(Salon B)*

7:45-8:00 **Begin Day 2.** *(Salon B)*
Mr. Jimmy Brumfield – Facilitator

8:00-8:30 **ASR's impact on long life infrastructure.** *(Salon B)*
Mr. Gerald "Jerry" Voigt – President and CEO, American Concrete Pavement Association (ACPA)
AND
Mr. Steven Kosmatka – Staff Vice President, Research and Technical Services, Portland Cement Association (PCA)

8:30-10:45 **ASR prevention in new construction.** *(Salons A and C)*
Breakout group discussions on Topic #2

10:45-11:00 **Break**

11:00-12:00 **Summary presentations from Group Leaders and group recommendations on Topic #2.** *(Salon B)*
Mr. Jimmy Brumfield – Facilitator

12:00-1:30 **Lunch** *(On your own)*

1:30-3:00 **ASR mitigation in hardened concrete.** *(Salons A and C)*
Breakout group discussions on Topic #3

3:00-3:15 ***Break***

3:15-4:15 **Summary presentation from Group Leaders and group recommendations on Topic #3.** *(Salon B)*
Mr. Jimmy Brumfield – Facilitator

4:15-4:30 **Wrap up of Day 2.** *(Salon B)*
Mr. Jimmy Brumfield – Facilitator

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DAY 3 – Thursday, June 8, 2006

7:45-8:00 **Begin Day 3.** *(Salon B)*
Mr. Jimmy Brumfield - Facilitator

8:00-9:30 **How do we approach the inventory of structures and pavements?** *(Salons A and C)*
Breakout group discussion on Topic #4

9:30-9:45 **Break**

9:45-10:45 **Summary presentations from Group Leaders and group recommendations on Topic #4.** *(Salon B)*
Mr. Jimmy Brumfield - Facilitator

10:45-11:45 **Presentation of Workshop recommendations and Workshop wrap-up.** *(Salon B)*
Mr. Jimmy Brumfield - Facilitator

11:45-12:00 **Closing Remarks.** *(Salon B)*
Mr. John Bukowski – Deputy Director, Office of Pavement Technology, Federal Highway Administration

ATTACHMENT C

ALKALI-SILICA REACTIVITY (ASR) BENCHMARKING WORKSHOP
Summary of Presentations

June 6-8, 2006
Chicago, Illinois

Welcome. SAFETEA-LU legislation and goals/outcome of Workshop.
Mr. Gary Henderson – Director, Office of Infrastructure Research and Development, Federal Highway Administration

Gary Henderson welcomed the guests and provided the overall objectives of the workshop. Mr. Henderson recognized that the National Highway System is celebrating its 50th year. Alkali-silica reactivity (ASR) was noted as one of many causes of the recent overall decline of the National Highway System. This fact has resulted in the current SAFETEA-LU legislation targeting development and deployment of techniques to prevent and mitigate ASR.

SAFETEA-LU designated a significant amount of funds for furthering the development and deployment of techniques to prevent and mitigate alkali-silica reactivity. Of the legislation, $2.45 million per year, from 2006 through 2009, has been assigned to provide for ASR efforts described in the legislation. The FHWA devised this Benchmarking Workshop shortly after SAFETEA-LU was signed in order to gain perspective on what the FHWA should consider in the ASR Program. The Benchmarking Workshop was specifically designed to listen to other Agencies, State DOT's, Academia, and Industry. The outcome of this workshop will help define the needs required to prevent and mitigate ASR. Participants in this workshop were asked to do several things during the workshop:

- First, each participant was asked to listen to the presentations. The presentations were specifically requested to discuss the current State-of-ASR from members of Academia, Industry, State Departments of Transportation, and other Federal Agencies.
- Secondly, each participant was requested to take an active role participating in the discussion groups. During discussions participants were to focus on several different aspects of ASR. We ask that as a group the participants identify potential elements for the upcoming ASR Program in addition to establishing their relative importance.

Mr. Henderson charged the participants with several things that must be considered when developing the potential elements for the ASR Program. Firstly, the guidelines established by the legislation must be upheld. Secondly, the ASR Program must be completed within 4-years and within the designated funding. Suggested elements of this program should be accomplished within these boundaries.

ASR development and deployment procurement plan.
Mr. Charles Nurse – Contracting Officer, Office of Acquisition Management, Federal Highway Administration
AND
Ms. Sarah Berman – Contracting Specialist, Office of Acquisition Management, Federal Highway Administration

Sarah Berman described the mechanism by which the FHWA plans to manage the SAFETEA-LU described ASR Program. A solicitation will be made available on the FedBizOpps.com webpage that will outline the activities within the ASR Program. Proposals will be submitted to the FHWA and multiple contractors will be selected. It is anticipated that contracts between the FHWA and successful solicitors will be of the Indefinite Delivery/Indefinite Quantity type.

Ms. Berman requested that participants within the Benchmarking Workshop review the solicitation and provide feedback to the FHWA. Feedback could take the form of questions, comments, concerns, or ideas regarding the solicitation. Feedback obtained by the FHWA may be used to change the solicitation.

ASR in highway structures and pavements: What have we learned and what do we still need to know from research?
Dr. Surendra Shah – Director, Center for Advanced Cement-Based Materials (ACBM)

Dr. Surendra Shah provided an overview of ASR along with a brief history of research that has been conducted on ASR and where further research is needed. Dr. Shah provided overviews in eight specific areas: ASR – Old and Persistent; ASR – Mechanism 101; Factors Affecting Expansion; Recognizing ASR; Mitigation Strategies; Test Methods; Some New Approaches; and What Do We Still Need To Know.

Alkali-silica reactivity was first identified as a cause of concrete deterioration in 1940. Since that time, much has been learned about the cause and prevention of ASR. However, ASR still continues to be a problem. Distresses caused by ASR have been noted in concrete structures that are over 100 years old and in structures that are only a few years old. The problem of ASR is not limited to certain types of structures, but has occurred in large structures, bridges, and pavements.

ASR is basically a two step process. First, alkali hydroxides combine with silicas contained in reactive aggregates to form an alkali-silica gel. Secondly, when moisture is combined with the alkali-silica gel, expansion will occur. This expansion is what causes damage in a concrete element.

Dr. Shah identified a number of factors that can affect expansion due to ASR. First is the nature of the reactive silica, which refers to the crystalline structure of the silica. The next factor affecting expansion discussed was the amount of reactive silica available to combine with the alkali hydroxides. A pessimum percentage of silica often exists, with expansion increasing as silica content increases to a point and then expansion decreases. Thirdly, expansion increases as the reactive material's particle size decreases, to a point. Similar to the amount of available silica, the amount of available alkalis also affects the amount of expansion. The ratio of reactive silica to alkali and total alkali content are both important. The final two factors affecting expansion discussed were the amount of moisture and temperature. Dr. Shah noted that the use of deicers also influence ASR. There has been both field and laboratory studies that suggest that some deicers have increased the potential for ASR.

The next overview covered by Dr. Shah was how to recognize ASR. There are basically two methods for recognizing ASR: field and laboratory studies. Field studies involve map-cracking and visual observation of distresses. Laboratory studies include petrographic evaluations, XRD, scanning electron microscopes (SEM), EDXA and cores.

A number of mitigation strategies were identified. One approach is to eliminate the use of reactive aggregates within the concrete mixture. Another approach is to reduce the total mixture alkalinity. This can be done by reducing the cement content and through the use of low alkali cement. Supplementary cementitious materials (SCMs) such as fly ash, ground slag and silica fume have also be effective at mitigating ASR. Lithium compounds are also used to mitigate ASR.

It has been known since the 1950's that lithium compounds can be used to effectively control ASR. In the presence of lithium, the ASR product forms, but is not deleteriously expansive. Dr. Shah indicated that the exact mechanism that helps prevent expansion is not completely understood. The most effective form of lithium is a lithium nitrate ($LiNO_3$). However, lithium is not equally effective with all aggregates.

Dr. Shah presented several theories on why lithium controls expansion. First, the lithium alters the ASR product composition resulting in less expansion. Secondly, the lithium reduces the dissolution of silica within the mixture. Thirdly, lithium decreases the repolymerization of silica and silicates. Finally, the repulsive forces between colloidal ASR gel particles are reduced by lithium resulting in less expansion.

Dr. Shah identified the following test methods that are available to evaluate the potential for ASR:

- C 295, Petrographic Examination of Aggregates for Concrete, used to identify potentially reactive constituents and rock types
- C 289, Potential Alkali-Silica Reactivity of Aggregates (Chemical Method), measure extent of aggregate dissolution (dissolved SiO2 and reduction in alkalinity) in NaOH solution, -300 mm, 80ºC, 24 hr
- C 227, Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method), high alkali cement, 38ºC, 6 mo
- C 1260, Potential Alkali Reactivity of Aggregates (Mortar-Bar Method), bars immersed in 1-M NaOH solution, 80ºC, 16 d
- C 1293, Determination of Length Change of Concrete Due to Alkali-Silica Reaction, high alkali cement, 1 yr

- C 441, Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction, mortar test with Pyrex glass, 38ºC, 14 d
- C 1567, Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method), same as C 1260 for mineral admixtures

Dr. Shah stated that there currently there are many standards that deal with ASR, primarily because none of the tests are entirely reliable. He listed the following shortcomings with the different methods:

- Not very reliable (C 289, C 227, C 441,C 1260)
- Long Testing Time (C 227, C 441, C 1293)
- Aggressive in Nature (C 1260, C 1567)
- Alkali Leaching (C 227, C 441, C 1293)
- Aggregate size effects (C 227, C 441, C 1260, C 1567)

Additionally, there is not much agreement between some tests. Some reasons for these differences include the effect of temperature, particle size, size of specimen and the availability of alkalis.

New test methods developed to measure the potential for ASR should be reliable and reproducible, accelerated, based on fundamental principles, able to evaluate the influence of aggregate size, able to evaluate SCMs, and able to evaluate lithium compounds. Some of the new approaches that currently exist include the Dilatometer Test, Chemomechanics, Probing at Nanoscale, and Non-destructive Evaluations.

Work that still needs to be conducted with respect to ASR includes a better understanding of the basic mechanism of swelling and the role of calcium. Little is known about how lithium mitigates expansion; therefore, more work is needed to understand the influence of lithium. With respect to pavements, a better understanding is needed on the role of deicers in ASR. Some deicers have accelerated ASR. Another aspect needed is a better understanding of how SCMs and lithium influence pore chemistry. These needs can likely be solved by development of a fundamental model on the mechanisms of ASR. This fundamental model should help develop a practical, mechanically-based screening test.

An industry perspective on implementation of ASR requirements in specifications for concrete bridges and pavements.

Dr. Anthony Fiorato – Chairman of the Board, ASTM International

Dr. Anthony Fiorato provided an industry perspective on the implementation of ASR requirements in specifications for concrete bridges and pavements. His discussion points included factors controlling ASR, specifications approaches, test methods and industry needs.

ASR is a two-step process. Initially, alkalis combine with silica to produce the reaction product. When this product combines with water, expansion occurs. Therefore, there are three requirements for deleterious expansion due to ASR: reactive silica, sufficient alkalis and available moisture. Almost all specifications address the reactive aggregates (silica); however, many contract specifications do not address alkalis or moisture.

Construction specifications are the documents that facilitate commerce. They define the key information between a buyer and seller to facilitate the commerce and to assure performance. The buyer (owner) uses the specifications to establish the desired properties for materials and construction. Contract specifications can take a number of forms including prescriptive, performance or a combination of the two. Prescriptive specifications are written in terms of specific composition, ingredients and chemical or physical properties. Performance specifications are written exclusively in terms of attributes that relate to performance to satisfy the needs of the user. Hybrid specifications include both prescriptive and performance requirements. Specifications related to ASR generally include language dealing with the use of non-reactive aggregates, limiting alkalis, the use of SCMs and/or use of chemical inhibitors. With respect to aggregates, a number of methods are available to specify non-reactive materials. Fiorato indicated specifying a certain field service history was the best method. Petrographic examination (ASTM C295 and C856) is another method of identifying reactive aggregates. Another test that can be utilized in evaluating aggregates is the concrete prism test in accordance with ASTM C1293. A screening tool that can also be used includes the accelerated mortar bar test (ASTM C1260 or AASHTO T303).

Another method of specifying low ASR potential concrete is to limit the amount of alkalis. This can be done by limiting the number of alkalis in the cement or by limiting the amount of alkalis in the mixture.

Some agencies have required the use of SCMs in an effort to minimize expansive ASR potential. Specifications for SCMs are provided below:

ASTM C595 and C1157 for blended cements
ASTM C989 for slag
ASTM C618 for fly ash and natural (pozzolans)
ASTM C1240 for silica fume

When requiring SCMs in a prescriptive specification, there are two items needed. First, the characteristics (fly ash, slag, calcined clay, or silica fume) should be specified. Next, the minimum content should be specified. In some cases, agencies have specified a minimum SCM content based upon the amount of alkalis in the cement. Fiorato provided an example for inclusion of SCMs in a performance specification. First, the aggregate source should be tested in accordance with ASTM C1260 (accelerated mortar bar test). If the 14 day expansion is less than or equal to 0.10 percent, then no special provisions are needed. However, if expansion is greater than 0.10 percent, then test for use of SCMs either as blended cement or admixture. ASTM C1567 should be used to test the effectiveness of the SCMs. If expansion in ASTM C1567 is less than or equal to 0.10

percent at 14 days, then accept the mixture at the same or greater dosage rate of SCMs. However, if expansion is greater than 0.10 percent at 14 days, then either change the dosage rate or materials.

Fiorato provided the following industry needs with respect to specification on ASR.

1. Set clear rules
2. Use established test methods for performance options
3. Apply the rules consistently (on a national basis?)

Results of the ASR SHRP Implementation Program and the AASHTO LEAD States Program from a State perspective.
Mr. Cecil Jones – State Materials Engineer, North Carolina Department of Transportation

The Strategic Highway Research Program (SHRP) was established in 1987 and provided $150 million to improve the performance and durability of pavements and to improve motorist and worker safety. Within SHRP, there was a clear aim that work under the program must be completed. Based on SHRP, there were 130 products that were delivered, five of which dealt with ASR. Three of these products were publications entitled:

1. ASR: An Overview of Research
2. Eliminating and Minimizing ASR
3. Handbook for the Identification of ASR in Highway Structures

The final two products dealing with ASR resulting from SHRP were test methods:

1. AASHTO T299, Rapid Identification of ASR Products in Concrete
2. AASHTO T303, Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars due to ASR.

Both AASHTO and FHWA took an active role in trying to implement the results from SHRP. AASHTO added staff in order to fast track standards resulting from SHRP and developed a task force on SHRP implementation. FHWA hosted numerous ASR showcases to provide technology transfer. An equipment loan program and round-robin laboratory program were also developed in order for agencies to utilize the SHRP developed tests. All of these activities and information were then handed off to an AASHTO ASR Lead State Team. This AASHTO ASR Lead State Team was comprised of about 30 states with the goal of deployment of ASR technologies. The ASR Lead State Team had the following mission:

"To provide a clearing house to share and deliver information and technical assistance in identification, prevention and rehabilitation of alkali silica reactivity to the public, private and academic sectors of transportation."

Accomplishments of the ASR Lead States Program included a national survey to identify the extent of the ASR problem and to determine the current activities of stakeholders. The Handbook for the Identification of ASR in Highway Structures was also updated with new information and a Draft Guide Specification on ASR Resistant Concrete was developed. A website was developed and a compilation of State specification was placed on the website. Jones indicated that there was very little uniformity in the State specifications.

At the conclusion of the ASR Lead State Program in 2000, a Lead State Transition Team was formed within the AASHTO Materials and Construction Subcommittees. These subcommittees were formed for monitoring existing mitigation sites, construction guidance and to provide an ASR data repository. Jones indicated that of these three items, only a fragmented ASR data repository had been accomplished.

Jones provided the following challenges with respect to ASR. First, there is not currently a structure in place for a national effort on ASR with funding. There are also staffing issues at both AASHTO and States. Most agencies do not have the resources to fund a dedicated staff to ASR. The final challenge is the perceived lack of need with respect to ASR.

Based upon the new SAFETEA-LU legislation, there is a new opportunity to further the amount of knowledge on ASR. This would include building on existing work and developing and deploying new technology. Jones indicates that the emphasis should be on deployment and implementation.

What can be implemented from the current research program?
Dr. Benoit Fournier – Manager of Advanced Concrete, CANMET

The FHWA has previously funded research on the use of lithium to control ASR expansion. Dr. Benoit Fournier provided an overview of what has been learned from laboratory and field evaluation using lithium compounds. Initially, Dr. Fournier described a research project recently completed and another research project that recently began. In 2003, the FHWA project DTFH61-02-C-00051, "Guidelines for the Use of Lithium to Mitigate or Prevent ASR," was completed. This guideline documents was based upon an extensive review of literature and current practice. Guidance provided a prescriptive dosage of lithium to be used for all aggregates. Another prescriptive dosage was recommended when used in combination with SCMs. Finally, the guidelines recommended the concrete prism test with the test being conducted for 2 years and expansion being less than 0.04 percent. Additionally, a modified version of the accelerated mortar bar test was recommended with the mortar bar soak solution including lithium.

In 2004, another large research effort was initiated by the FHWA. This project, "Lithium Technology Research Studies and Reports for Mitigation of ASR in Concrete," began in 2004 and will conclude in 2009. To date, three Task Orders have begun. The first has been completed and was used to develop a work plan for the overall project. The second, entitled “Research and Implementation of Lithium in Laboratory and Field,” will be completed in 2009. The final Task Order will revise the 2003 guidelines document based upon the research conducted within the second Task Order. These revised guidelines should remove the prescriptive requirements and provide more performance based guidelines.

The second Task Order described above will include evaluating the use of lithium for both new and hardened concrete to mitigate deleterious ASR expansion. Testing for new concrete will focus on accelerated test methods as well as the use of exposure blocks. Three test sites, in three different environments, have been set up to evaluate lithium using exposure blocks. Dr. Fournier indicated that results of testing to date show that one dosage rate of lithium for all aggregates is not appropriate. Lithium dosage should be based upon the aggregate mineralogy.

Treatment of ASR affected concrete with lithium has concentrated on determining the best method of applying lithium to hardened concrete. Three methods are currently being investigated: topical application, vacuum impregnation, and electrochemical methods. All three of these methods are being investigated in laboratory experiments. Two FHWA TechBriefs have been developed based upon the results to date: FHWA-HRT-06-069, “Selecting Candidate Structures for Lithium Treatment: What to Provide the Petrographer Along with Concrete Samples,” and FHWA-HRT-06-071, “Protocol for Selecting ASR Affected Structures for Lithium Treatment.”

Fournier also described an overview of several field studies for the application of lithium to ASR affected pavements and structures. In Idaho, on Interstate 84, approximately 100 lane miles of pavement have been affected by ASR. A test section approximately 3.7 miles in length was identified. On one-third of this test section, a single topical application of lithium was applied. On another third, two topical treatments were applied and on the final third three topical treatments were applied. These sections are currently being monitored. However, one lesson learned from the field trial was that salt precipitation resulted in a slick pavement surface which appeared to be a function of lithium dosage, environmental conditions and the condition of the concrete. Repeated water treatments to the pavement surface should improve the conditions.

Another field study on Interstate 94 in Idaho is currently being monitored. Field samples were obtained from this pavement and are currently being tested in the laboratory. Topical treatments where again utilized for the pavement.

Vacuum impregnation is currently being evaluated on barrier walls and some bridge piers. With the barrier walls, several vacuum treatment times were evaluated. These vacuum times were utilized to evaluate the influence of vacuum time on the depth of penetration of the lithium. Various combinations on the times of vacuum and number of applications are being evaluated. Samples of the barrier walls are also being obtained for laboratory testing.

On a bridge in Houston, Texas, both vacuum impregnation and electrochemical methods are being investigated. Lithium applications have been made; however, testing of the treated columns had not been completed.

Fournier offered the following as a summary on lithium for the concrete:

- Lithium nitrate is effective in controlling ASR in new concrete when used in sufficient dosage.
- Aggregate mineralogy plays a key role: testing of more aggregates types is needed for reliable guidelines.
- Testing for establishing appropriate lithium dosage rates for controlling ASR expansion should include: (1) concrete prism test (2-year, 0.04 percent expansion) recommended to determine lithium dosage rate at this time; (2) work is in progress to propose modifications to the accelerated mortar bar test, especially for ternary and binary systems; and (3) the accelerated concrete prism test (60˚) is promising.
- More work is needed to understand the mechanisms of beneficial actions.
- Work is needed to evaluate lithium in low-alkali systems.

The following summary was provided for the use of lithium for ASR affected concrete:

- Lithium shows promise for treating ASR affected concrete in the laboratory using small specimens immersed in lithium.
- Guidelines have been developed to help in selecting structures for lithium treatment.
- Analysis of data from lithium profiling in a pavement section (in-situ and blocks) after topical treatment has revealed very limited lithium penetration.
- Future focus on methodologies to force lithium into concrete in field structures is needed.
- Monitoring of ASR affected structures treated with lithium is required.

Federal Aviation Administration (FAA) experience with ASR.
Mr. Jack Scott – Civil Engineer, Safety and Standards Branch, Northwest Mountain Region, Federal Aviation Administration

Mr. Jack Scott provided an overview of the Federal Aviation Administration’s (FAA’s) experience with ASR. With respect to the aviation industry, the primary problem associated with ASR damage is foreign object debris (FOD). When sufficient expansion occurs to cause the concrete to degrade and break up, the resulting debris (FOD) can be sucked into jet engines causing costly damage.

In the past, the FAA utilized ASTM C33 as an optional requirement. However, it was recommended that low alkali cements be used for airfield paving in an effort to minimize deleterious ASR. In the 1990’s, the FAA began to recommend ASTM C295 (petrographic analysis), ASTM C289 (chemical test) and ASTM C227 (mortar base expansion). Scott indicated the test time for the mortar bar expansion test was a problem.

The FAA recommends the use of low alkali cement with a maximum equivalent alkali of 0.6 percent. Also, there is a concern with the availability of Type F fly ash. Scott stated that Type C fly ash was not as effective at minimizing deleterious ASR expansion. A revision made to the FAA guide specifications in the late 1990's was to also include testing in accordance with ASTM C1260 with a maximum of 0.1 percent expansion at 16 days and a modified version of ASTM C1260 for mitigation testing.

Based upon an experience in Oregon in which a 15 year old pavement exhibited deleterious ASR expansion, more specification revisions were made. Any laboratory conducting ASTM C1260 testing for FAA projects must be accredited under ASTM C1077. Also, both the coarse and fine aggregates shall be evaluated separately in accordance with ASTM C1260. Each aggregate source shall be evaluated separately. Additionally, aggregates shall be evaluated in combination using the modified ASTM C1260. All results must have measured expansions of less than 0.1 percent at 28 days.

Scott stated that the use of some pavement deicers appear to increase the potential for deleterious ASR expansion. Some deicers that have been used in the past or are currently utilized include urea, sodium acetate, sodium formate, potassium formate and potassium acetate. In addition to pavement deicers, aircraft deicers are also commonly used to prevent ice from building upon the aircraft. Ethylene glycol and propylene glycol were both mentioned as aircraft deicers. Scott provided several examples of deleterious ASR expansions that occurred in older pavements after some new pavement deicers were utilized. A research study under the Innovative Pavement Research Foundation (IPRF) to evaluate the effect of pavement deicers is currently underway Potassium acetate, potassium formate, sodium acetate and sodium formate all caused significant expansion in mortar bars containing reactive aggregates. Some deicers doubled the expansion seen in the standard ASTM C1260 test which uses sodium hydroxide. For this reason, the FAA is now recommending that the deicers be added to the soak solution when conducting laboratory testing. An Engineering Brief (EB 70) has been developed to take into account concrete pavements that will have deicers used. Additional research is being conducted through the IPRF to evaluate mitigation methods or deicer-ASR reactions. This work includes incorporation of Type F fly ash, granulated blast furnace slag, lithium nitrate, or a combination into the concrete. Scott then discussed some additional research work that will be conducted through the IPRF which include:

- Acceptance testing for combined aggregates using ASTM C1260 and C1567
- Blended cements for mitigation
- Techniques to mitigate ASR in mixes from deicer effects
- Develop training course on use of lithium in mixes
- Impact of lithium of fresh and hardened concrete
- Lithium field study in fresh concrete
- Techniques to maximize effectiveness of lithium topical applications
- Field application on existing ASR

Scott then provided a list of current needs relating to test methods which include:

- A short term test to evaluate the long term performance in the presence of deicers. Test limits are also needed.
- A test to evaluate the performance of pavements having exposure to deicers.
- A survey of airports using potassium acetate to evaluated field performance of various aggregates and mixes.

Department of Defense (DOD) experience with ASR.
Mr. Terry Sherman – Director, Transportation Systems Center, US Army Corps of Engineers

Terry Sherman of the USACE and Toy Poole of the US Army Engineer Research and Development Center provided an overview on the experiences with ASR by the Department of Defense (DOD) and US Corps of Engineers. Sherman listed numerous air force, army and naval airfields that have experienced deleterious ASR expansions. The airfields were located all over the US as well as some from overseas.

In the past, the DOD only had requirements for concrete made with reactive aggregates. If alkali-silica reactive aggregate are included, low alkali cement was required. Recently, a new Untied Facilities Guide Specification (UFGS) was developed that provided more requirements for concrete with respect to ASR (UFGS 32 12 11). Both the fine aggregate and coarse aggregate are tested in accordance with ASTM C1260. Additionally, the aggregates are tested in combination. If expansion is greater than 0.08 percent at 16 days, the mix is rejected. When using SCMs, the modified ASTM C1260 is utilized. The modified ASTM C1260 is used with low alkali cements combined with 25 to 40 percent fly ash, 40 to 50 percent blast furnace slag and lithium nitrate.

A new guide specification will be implemented soon by the DOD. This new guide specification will also include ASTM C1567. The navy also will mandate the use of fly ash or blast furnace slag. Exposure to deicer chemicals will also be evaluated.

Poole provided a brief overview of issues relating to ASR from the point of view of the Corps of Engineers. The biggest issue is the non-uniformity of ASR expansion in very large structures. This can cause realignment of various components of these large structures.

ASR’s impact on long life infrastructure
Mr. Gerald “Jerry” Voigt – President and CEO, American Concrete Pavement Association (ACPA)
AND
Mr. Steven Kosmatka – Staff Vice President, Research and Technical Services, Portland Cement Association (PCA)

Neither Voigt nor Kosmatka had formal presentations; rather each provided a series of questions and comments on the state of ASR. The following are the notes provided by Voigt and Kosmatka for their discussions.

Voigt began his presentation with a series of questions, which included:

How many people in this room believe that responsibility for the concrete mixture is being shifted more and more to the contractor? Please stand up. Look around.

How many people in the room are contractors? Everyone else sits down and only contractors stand up.

Now let me ask a variation… how many people feel this shift of responsibility is complete?

Those questions reveal the issue. Forgive me for being harsh and direct, but until this meeting room is filled with concrete pavement contractors, the risk of ASR in pavement structures will not be minimized no matter what progress you make about the chemistry or other technical issues.

The BAD NEWS… All of us in this room are part of the problem. We have focused on the details and debated the chemistry, blamed the other guy's material, looked for a silver bullet, but have not provided a system for the practitioners to make good decisions.

The GOOD NEWS… All of us in this room have the ability to be part of the solution if we focus on providing this needed systematic approach.

Some observations from our recent European Scanning Tour of Long Life Concrete Pavement:

What is LLCP? *Pavements optimized for a performance period in excess of 50 years, an extended time to first rehabilitation and minimal maintenance requirements.*

What material-related principles are being used in Europe?

- *Reliance on blended cements with performance requirements (Canada, Austria, Belgium and The Netherlands)*
- *Concept of better aggregate packing (at least 4 bins to blend aggregates – coarse and fine), which impacts many aspects of pavement design, including minimizing paste content and reinforcement*
- *Recycling old concrete and asphalt into lower course concrete slabs and in cement stabilized bases*

How do these material factors impact the pavements?

- *They allow alterations to the structural design elements to maintain the performance of a pavement without increasing the initial cost. More money is spent on the concrete and less on the reinforcement, for example. This more thorough approach to materials is the responsibility of the contractor working in a framework defined by a combined expert group including agency, academia and industry (materials, cement and contractor).*

How does European contracting methodology affect this issue?

- *Two basic methods are used in Europe, normal bid project (sometimes selected by best value rather than lowest price), and PPP – public private partnerships. Under normal contracting time is allowed for innovative ideas and bid development after announcement time. The contractors have graduate-level engineers that are responsible for the company's materials and concrete (the transfer of responsibility is complete and system fosters the companies to be knowledgeable as well as responsible because they are rewarded for their innovation and their ingenuity.)*
- *Public-private partnerships are as much as ten years ahead of the US (although we are seeing this trend here too). PPP's place the responsibility for design, construction and maintenance on the contractor team. The responsibility is purely on the shoulders of the contractor or PPP team and the most common period of responsibility is 30 years.*

Back to the Challenge… We see three basic principles or drivers at play

1. The transfer of responsibility to the contractor for the concrete mixture

   The macro issues at agencies is driving this shift. The attrition of experienced personnel and the desire for warranties are keys. A systematic approach must be developed for agencies to "let go" and complete this transfer of responsibility (and risk). Otherwise we will continue to build at a higher risk for ASR (The old adage, "when everyone is responsible, no one is responsible," applies).

2. Lack of an analysis system for practitioners

   The fact is that most practitioners do not understand ASR; they do not understand concrete chemistry. The realm of ASR is discussed at a plane above where it should be. BUT… we are asking them to be more responsible for bringing together materials to build projects. In the future it really shouldn't matter what materials you combine to produce concrete with regard to ASR if a reliable evaluation system can qualify <u>the mixture</u> for <u>the environment</u> in which it will be used.

3. The lack of quick and reliable performance tests to feed the systematic approach

   To achieve a systematic approach will require performance tests that reliably qualify a mixture quickly, so that they can be reasonably implemented. Contractors cannot wait a year for test results. They bid a project and often have to start the contract within 30-45 days! Contracts for materials are developed ahead of the time when bids are submitted.

   The test also should be flexible enough to qualify a mixture depending upon other factors, like ambient temperature and use of materials like Potassium Acetate.

Summary Question: The legislature stipulates “Further development and deployment” of ASR technology, but we need some fundamental research to get the quick, reliable performance test to underpin a systematic approach. Can we do that within the spirit of the legislation?

Now Steve Kosmatka from PCA will add some further ideas to this perspective…

Summarize:
1. Contractor is responsible for mix
2. We need a system to reliably and universally qualify mixtures for a specific environment
3. Quick performance tests (less than 30 days)

Great ideas and observations came out of yesterday’s discussions. Let’s evaluate the importance of 10 of the observations in relation to the ASR challenges that a contractor faces in building long life concrete structures.

As we go through these, keep this question in mind: <u>Does the activity benefit the contractor, or construction of, long life pavements and structures?</u>

1. Flexibility for material selection in assessment or mitigation protocol: look at the TXDOT approach with 8 ways to control ASR. Also the AASHTO and CSA protocols also provide great flexibility allowing a variety of materials and approaches; and there are many other examples. Beneficial to long life? Yes, produces economical solutions with locally available materials to maximize ASR control. Also, the contractor can change materials on the job due to seasonal or supply changes.

2. It was observed by several people that there are different criteria and tests for different materials in numerous standards and specifications which vary with each state. Beneficial? Probably not, because everyone is playing by different rules, creating confusion for material suppliers; specifiers, contractors, etc. Dr. Fiorato well stated Al Innis’s axiom--Set clear rules; use established test methods for a

performance option; and apply the rules on a national basis. Without that, we have the chaos in specifications we see today.

3. Develop protocols to use existing tests relating to field conditions and performance, including mitigation strategies. Benefit to long life? Absolutely. We may well be able to fully control ASR for decades with the methods we have if we understand their limitations and field impact.
4. Develop accurate, fast, reliable tests and integrate them into the assessment system, especially if the entire concrete mixture can be evaluated for the environmental and service conditions. Benefit? Yes. A strong benefit to everyone involved in a long life project. Also, new approaches to control ASR could be adopted sooner.
5. Ignore ACR. Benefit to long life? No. Although rare, we cannot ignore ACR as it is just as destructive as ASR.
6. Development of tests that evaluate multiple durability concerns simultaneously. Benefit? Yes, because we do not currently take into account the synergistic impact of multiple exposure conditions such as freeze-thaw, deicers, and sulfates in different environments, in how they may accelerate ASR.
7. Correlate performance tests and criteria to the duration with which ASR is controlled. Benefit? Yes, especially on Private Public Partnerships where a contractor and the banker assume risk over 30+ year periods. Is today's rapid mortar bar or concrete prism tests predicting safe performance for 50 years? I don't know. We have only been using them for about 15 yrs.
8. Databases and models. Benefit? Maybe, but only if the information is kept up to date with pertinent data and the model is comprehensive and easy to use and available to everyone.
9. Maintain all current test methods because someone somewhere is using them. Benefit to long life structures? No. We currently have methods that if used, give the user a false sense of security. Tests such as ASTM C 289 and C227 in current form are overly unreliable. Some of you know I am not a big fan of the C441 Pyrex glass test. As we develop new and better tests, we need to let some go to the archives.
10. Develop a protocol to evaluate how new substances, such as new deicers, impact ASR, including mechanism. Benefit for long life pavements? Based on the airfield deterioration discussions yesterday, yes. Appropriate tests must address the changing needs of society so that we can maintain the long life expectancy of concrete in transportation structures.

That is enough examples, but you can see how this benefit analysis can be applied to everything we discuss this week and how it directly impacts the contractor and the construction of long life pavements or bridges.